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RELATIONAL DISCRIMINATION BY PIGEONS IN A GO/NO-GO PROCEDURE WITH COMPOUND STIMULI: A METHODOLOGICAL NOTE

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A go/no-go procedure with compound stimuli typically establishes emergent behavior that parallels in structure and typical outcome that of conventional tests for symmetric, transitive, and equivalence relations in normally capable adults. The present study employed a go/no-go compound stimulus procedure with pigeons. During training, pecks to two-component compounds A1B1, A2B2, B1C1, and B2C2 were followed by food. Pecks to compounds A1B2, A2B1, B1C2, and B2C1 re-started the 30-s stimulus presentation interval. The absence of pecking to those compounds for 30 s ended the trial. Subsequent tests presented these components in new spatial arrangements and/or in recombinative compounds that together corresponded to conventional tests of symmetry, transitivity, and equivalence: B1A1, B2A2, C1B1, C2B2, A1C1, A2C2, C1A1, C2A2 vs. B1A2, B2A1, C1B2, C2B1, A1C2, A2C1, C1A2, C2A1 (positive vs. negative instances of symmetric, transitive, and equivalence relations). On tests for symmetric relations, all pigeons behaved in a manner consistent with training on both positive instances (i.e., by responding) and on negative instances (i.e., by not responding). By contrast, the pigeons' behavior on tests for transitivity and equivalence was inconsistent with baseline training, thus failing to show the recombinative discrimination performance that is typical of normally capable humans when trained and tested using the go/no-go procedure with compound stimuli.

Key words: Go/no-go procedure, compound stimuli, stimulus equivalence, key peck, pigeons

The matching-to-sample procedure is often used to teach conditional discrimination baselines and to test for emergent stimulus-stimulus relations that assess whether the baseline conditional relations are equivalence relations (showing the properties of reflexivity, symmetry, and transitivity). For example, after establishing conditional stimulus-stimulus relations between stimuli from Sets A and B (AB) and between stimuli from Sets B and C (BC), stimulus equivalence is demonstrated if relations BA, CB, AC, and CA emerge without further training (Sidman & Tailby, 1982). Such emergent behavior is the typical outcome of methodologically sound equivalence studies with humans (e.g., McIlvane, Serna, Dube, & Stromer, 2000; Sidman, 1994).

By contrast, most studies that have used matching-to-sample procedures in efforts to demonstrate equivalence classes with nonhumans have produced negative results (e.g., Sidman, Rauzin, Lazar, Cunningham, Tailby, & Carrigan, 1982). One reported outcome of matching-to-sample procedures with nonhumans, for example, is the development of stimulus control by compound stimuli that include not only the nominal stimuli – typically visual forms – but also the locations in which these stimuli appear (e.g., Iversen, 1997; Iversen, Sidman, & Carrigan, 1986; Sidman, 1992). Thus, when nominal stimulus locations are varied on tests for stimulus equivalence, the controlling stimulus-location compounds are not preserved and the test outcomes are negative.

The development of nominal sample and/or comparison stimulus-location compounds can be avoided by presenting the nominal stimuli either successively or side-by-side in the same location using a go/no-go procedure. Frank and Wasserman (2005) used this approach to demonstrate symmetry in pigeons. One procedural variable that might have been important was intermixing both arbitrary and

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identity relations, perhaps encouraging the development of prerequisite stimulus control topographies (cf. Lionello-DeNolf, 2009; Urcuioli, 2008).

Zentall and Hogan (1975) reported a go/no-go alternative to the intermixture procedure. They taught pigeons to peck circular keys bisected into two halves that were either the same color or different colors (the latter displaying two different colored semi-circles), reporting positive results on tests for generalized identity and oddity relations. That interpretation was questioned by Carter and Werner (1978). They suggested that the results could be explained as mere discriminative control by homogeneous vs. heterogeneous displays (i.e., circular vs. semicircular stimuli).

The present study with pigeons was inspired by recent studies with humans that used go/no-go procedures with form-compounds displayed side-by-side on a single key (Debert, Huziwara, Faggiani, De Mathis, Simões, & McIlvane, 2009; Debert, Matos, & McIlvane, 2007; Perez, Campos, & Debert, 2009). Undergraduate students were taught to respond to A1B1, A2B2, A3B3, B1C1, B2C2, and B3C3 compound stimuli and not to respond to A1B2, A1B3, A2B1, A2B3, A3B1, A3B2, B1C2, B1C3, B2C1, B2C3, B3C1, and B3C2 compounds. When these AB and BC relations were established, BA, CB, AC, and CA relations emerged without further training – corresponding to positive outcomes on conventional tests for symmetry, transitivity, and equivalence. Might pigeons show similarly emergent behavior if they were given a go/no-go training with compound stimuli using the procedure of Zentall and Hogan (1975)? The problem of homogeneous vs. heterogeneous displays would not arise because all displays presented in this application of the go/no-go procedure would be heterogeneous.

METHOD

Subjects were four pigeons (*Columba livia*). Two (P10 and P11) had been taught earlier to discriminate geometric forms. Pigeons P9 and P21 were naïve. All were maintained at 85% of free-feeding weight. Water and grit were available *ad lib*. Illumination followed a 12:12 hr light/dark cycle (lights on at 7:00 am). Sessions were run daily at the same hour.

Apparatus

Two operant conditioning chambers from Med Associates® were used. A 7.5 × 8.0 cm window was located 9.5 cm above the floor, centered on the back wall of the chamber. Through that window, the pigeons could peck compound stimuli presented on a 15-inch (38.1-cm) touchscreen-fitted monitor (Elo TouchSystems, Model 1515L) that also identified the pecks. Contingent mixed grain reinforcers were delivered automatically through an opening centered on the right wall located 2.5 cm above the floor. All experimental operations were controlled by a hardware interface (KPORT, Brazil) and a Visual Basic® software. Each chamber was enclosed within a sound-attenuating chamber with a fan that provided ventilation and masking noise.

Each compound stimulus was a 3 cm diameter circle bisected into two halves with different colors (components); the remainder of the monitor screen was white. Component stimuli were arbitrarily divided in two potential classes. Class 1 was comprised of red (A1), blue (B1) and orange (C1) and Class 2 was comprised of green (A2), yellow (B2) and purple (C2).

Procedure

Baseline training. This training was conducted to establish discrimination of ''related'' from ''not-related'' compounds. Related compounds were A1B1, A2B2, B1C1, and B2C2. Not-related compounds were A1B2, A2B1, B1C2, and B2C1. Each component of both related and not-related compounds was presented in fixed positions during training (e.g., A1 and B1 were always on the left and right, respectively, in the A1B1 compound). Each compound was displayed for at least 30 s. Responding to related compounds A1B1, A2B2, B1C1, and B2C2 was followed by food on variable interval schedules (P9 and P10, VI 60 s [range: 1–120 s]; P11 and P21, VI 15 s [range: 1–30 s). The ≥ 30-s requirement interacted with the VI schedules. If the programmed VI was < 30 s, then responses to related compounds could be followed by hopper activation and another VI value was then added to that trial. This feature meant that more than one hopper activation could occur per trial. If the programmed VI value

was > 30 s, however, no hopper activations occurred. Duration of hopper activation was adjusted periodically in order to maintain the pigeons' weights at 85% *ad lib.*

Regarding not-related compounds, every peck to A1B2, A2B1, B1C2, and B2C1 re-started the 30-s display interval. Trials ended only after 30 s without a peck. Intertrial intervals of at least 10 s separated all trials. During such intervals, the screen went black. Any pecks re-started the 10 s interval. Thus, trials started only when no intertrial interval peck had occurred for 10 s.

Initially, training included only A1B1, A2B2, A1B2, and A2B1 (AB training). Criterion was set at a discrimination ratio of 96% for three successive sessions (i.e., responses to related compounds/responses to all compounds* 100); in addition, pigeons had to respond to all related compounds and not to respond to all not-related compounds in each baseline training session. When the AB criterion was met, BC training commenced (B1C1, B2C2, B1C2, and B2C1). When the BC criterion was met (also 96% for three successive sessions and to respond to all related compounds and not to respond to all not-related compounds), AB and BC trials were intermixed (combined AB and BC training). The first row of Figure 1 summarizes the trial types that were presented during training.

AB training and BC training sessions presented 14 times each of the four types of compounds. All trial types appeared in alternating 4-trial blocks that presented each trial type once. During combined AB and BC training sessions, each compound was presented 7 times and each occurred once in successive 8-trial blocks. Trials were arranged such that related and not-related compounds could occur a maximum of three times in succession.

Test procedures. A single *Symmetry Test* session displayed components of related and not-related compounds in spatial positions reversed from those occupied during training (see Figure 1, row 2). Symmetry test compounds were B1A1, B2A2, C1B1, and C2B2 (related) and B1A2, B2A1, C1B2, and C2B1 (not-related). Test sessions had 144 trials. The first test-session block presented 8 trials, one of each AB and BC baseline compounds. Subsequently, five 24-trial blocks each presented 16 baseline trials (each twice) and 8 symmetry test trials (each once). Finally, a 16-trial block presented each of the baseline and symmetry test compounds. Baseline trials had their previous consequences. All test trial responses went unreinforced. Reinforcing responses to baseline trials was intended both to maintain these established relations and to forestall effects of pervasive extinction during testing. Trials were arranged such that extinction could occur a maximum of three trials successively.

Prior to separately conducted *Transitivity Test* and *Equivalence Test* sessions, pigeons were required to meet the baseline-learning criterion once again. Test compounds (Figure 1, row 3) recombined components that had not been displayed together but had been displayed with common third components. Sessions had 72 trials. The first 8-trial block of the *Transitivity Test* contained the eight baseline compounds. There followed four 12-trial blocks that included the 8 baseline and the 4 transitivity test compounds. The session concluded with a 16-trial block that presented 8 baseline trials (each compound once) and 8 transitivity test trials (each compound presented twice). Other procedure details were the same as described for symmetry test. Two transitivity test sessions were conducted.

Equivalence Test sessions had the same basic structure as transitivity test sessions. However, the related and not-related test compounds reversed the spatial positions of those presented on the transitivity test (compare Figure 1, rows 3 and 4). Due to experimenter error, Subject P11 was given its first transitivity and equivalence tests in the same session.

RESULTS

Figure 2 presents training results. Pigeons received from 9–74 AB sessions, 5–18 BC sessions, and 3–18 combined AB and BC sessions. Although all met the 96% discrimination ratio during these sessions, P9 (during AB training) and P11 and P21 (during combined AB and BC training) responded occasionally to the not-related compounds. In both cases, 3–4 further training sessions were given to eliminate such responding. Thus, the *de facto* criterion for these birds was virtually 100% accuracy in responding to related and not responding to not-related compounds.

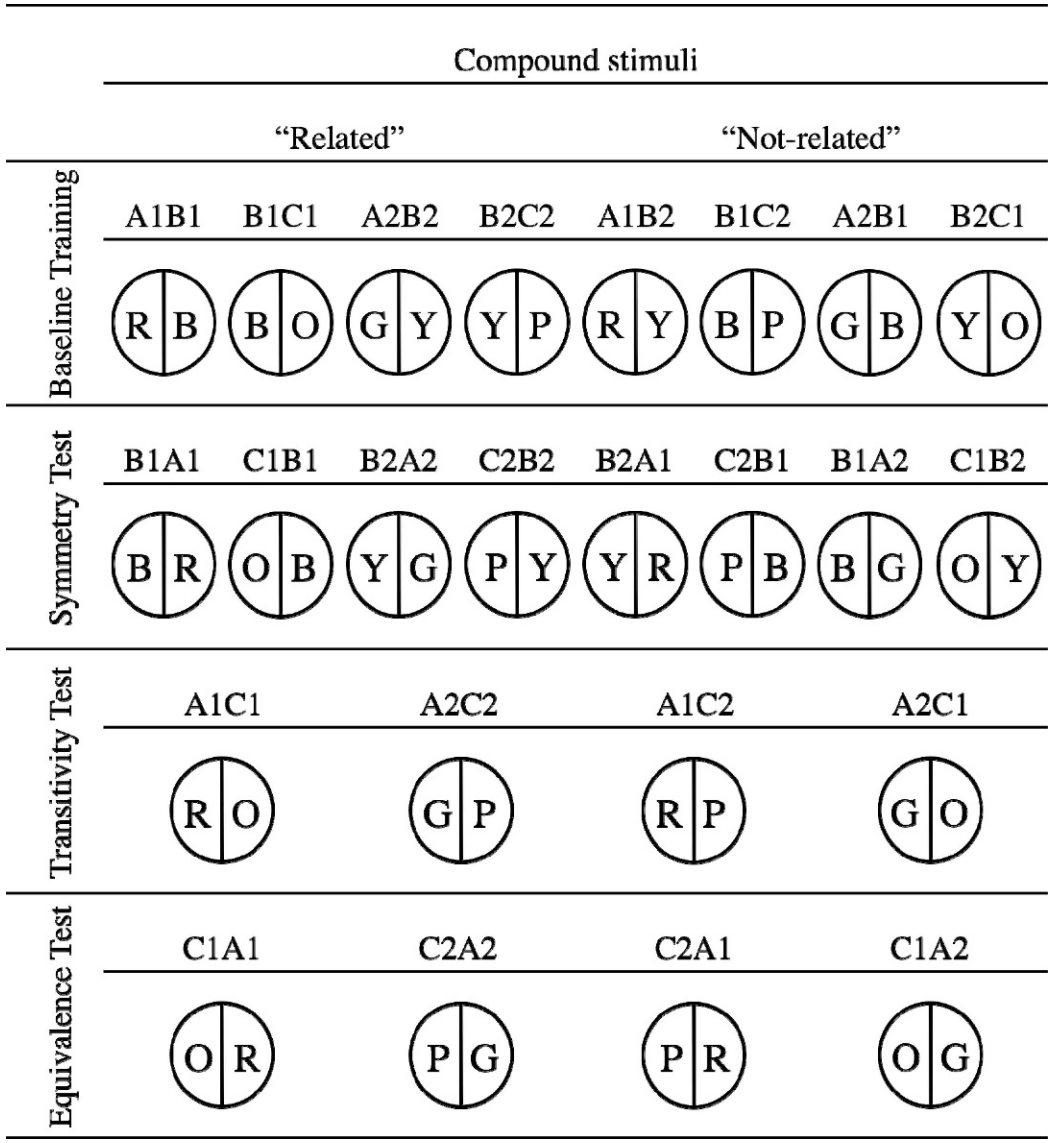

Fig. 1. Illustration of the compound stimuli presented during the experimental phases and their designations. R indicates red; B, blue; O, orange; G, green; Y, yellow and P, purple.

Figure 3 presents the highly positive symmetry test results. During testing, the response range on baseline trials with related compounds was 267–800 and the range on the corresponding symmetry test trials was comparable (223–432). Response range on baseline trials with not-related compounds was low (0–27) and the range on symmetry test trials was lower still (0–4).

Figures 4 and 5 present the transitivity and equivalence test results, which were negative in each of the two test sessions. Responses to the baseline related compounds were fairly high throughout whereas those to the baseline not-related compounds were low. Thus, the baseline relations were maintained during testing. Responses on related vs. not-related on all transitivity and equivalence test-trial compounds were highly variable, and they were thus not consistent with results that would be expected given equivalence class formation.

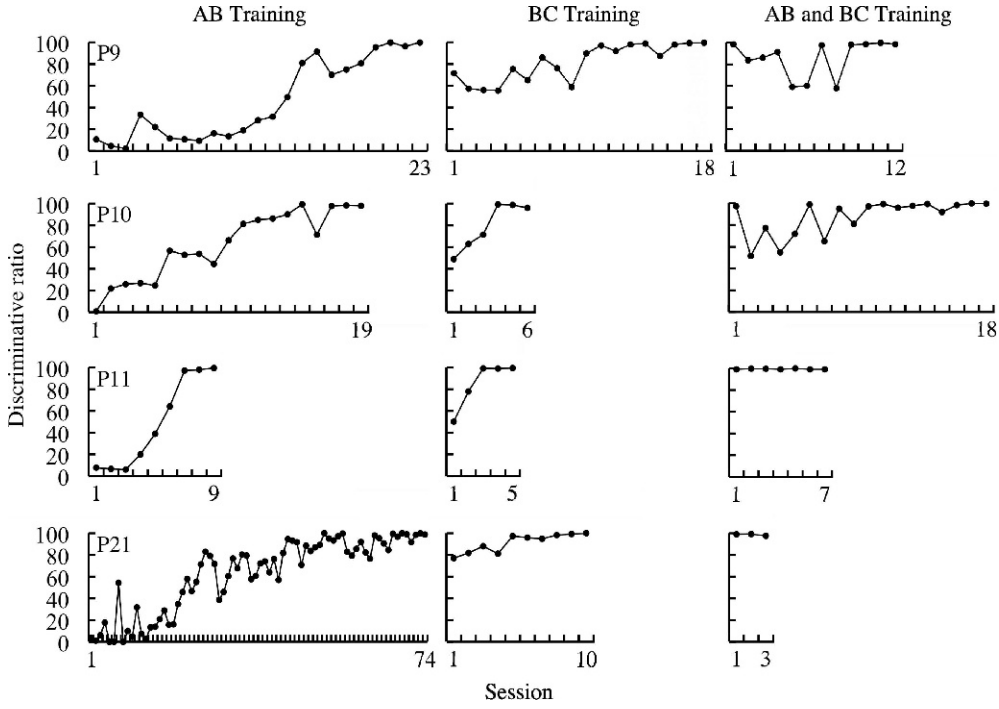

Fig. 2. Discriminative ratio for each session during AB training, BC training and AB and BC training for Subjects P9, P10, P11 and P21.

Viewing results on the transitivity and equivalence tests as a whole, there was evidence that some pigeons responded differentially to the test trial stimuli themselves. Some response rates to test compounds were high, some were intermediate, some were low, and some were nil or virtually so. In certain cases, for example, there was evidence of conditional discrimination on test trials (e.g., P10, second transitivity session in which responses to potentially not-related compounds were high and those to potentially related compounds were virtually nil). Whatever the bases for discriminating test components (simple discriminative control, other stimulus-stimulus relations [cf. Sidman, 1990], etc.), however, these discriminations appeared idiosyncratic in nature and clearly not consistent with transitive or equivalence relations.

DISCUSSION

This experiment evaluated whether symmetry, transitivity, and equivalence relations could be documented in pigeons via a go/no-go procedure with compound stimuli. On the symmetry tests, the discrimination ratios were very high – results that are consistent with those reported by Debert and colleagues (2007, 2009) with normally capable humans. For the transitivity and equivalence tests, however, the results were markedly different.

How does one interpret the present findings? The symmetry test results are in line with Frank and Wasserman (2005) and Urcuioli (2008). The go/no-go procedure eliminated the need to define separate sample and comparison stimulus locations, temporal ordering, and associated stimulus functions. Indeed, although the spatial locations of the components of the compounds did change somewhat on the symmetry tests, they merely reversed locations (analogous to merely ''flipping'' the stimuli horizontally). Pigeons were still given only one location to respond. Thus, one might argue that spatial separation of stimuli in typical matching-to-sample stimuli – which often does establish nominative stimulus-locations compounds in nonhumans (e.g., Iversen, 1997; Iversen et al., 1986; Sidman, 1992) – may be a matter of *degree* of spatial displacement rather than of spatial displacement *per se*. Moreover, positive symmetry

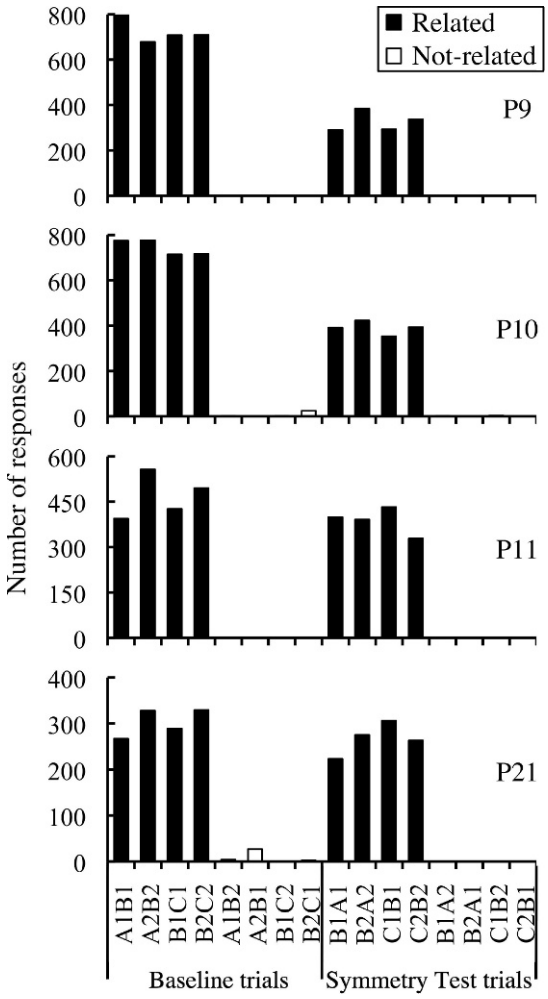

Fig. 3. Number of responses to baseline and symmetry test compound stimuli during symmetry test for Subjects P9, P10, P11 and P21. The left portion presents the baseline compounds. The right portion presents the symmetry test compounds. Black columns refer to ''related'' compounds and white columns refer to ''not-related'' compounds.

results were obtained without intermixing arbitrary and identity trials (see Lionello-DeNolf [2009] for further discussion of this issue).

Earlier studies with pigeons showed positive results for transitivity and negative results for symmetry tests (e.g., D'Amato, Salmon, Loukas, & Tomie, 1985) when the standard matching-to-sample procedure was used. Some authors (e.g., Frank & Wasserman, 2005) argued that these differences could be attributed to changes in temporal order and/or differences of sample and comparison stimulus locations between training and testing conditions that occur only in symmetry tests. However, the results of the transitivity tests reported here suggest that it is not enough to present the stimuli in the same position as in training in order for an emergent relation be documented. Moreover, the results of the symmetry test suggest that it is not necessary for the stimuli to appear in the same position as in training for an emergent relation to develop. Thus, our results appear to call into question the adequacy of stimulus position-based accounts of the type offered by Frank and Wasserman.

One might suggest that all of the behavior exhibited in this experiment could be accounted for by simple discriminative stimulus control and primary stimulus generalization. This line of argument considers the position reversal of symmetry-test stimuli as inconsequential – the colors remained the same combinations as were presented during training. Possibly related findings have been reported by and interpreted as such by Watanabe, Sakamoto, and Wakita (1995). These investigators taught pigeons to peck paintings by one artist (e.g., Monet) and to refrain from pecking those of another (e.g., Picasso). When the paintings were reversed subsequently in left-right orientation, accurate discrimination was maintained.

Are the findings of Watanabe and colleagues (1995) truly comparable to the present ones, however? That interpretation seems questionable. Pigeons in the latter study could master between-painting discriminations merely by attending to any single invariant stimulus feature in each – features that were preserved even in left-right orientation reversal. By contrast, the present procedure required birds to attend to *both* components of every compound stimulus to which they were exposed. That requirement is similar on its face to those required in typical matching-to-sample symmetry test procedures that merely reverse the positions of sample and comparison stimuli from those occupied during training. Moreover, the procedure of Frank and Wasserman (2005) merely re-ordered the presentation of training stimuli. Thus, pigeons could master the task merely by remembering both stimuli (regardless of order) of component pairs that were and were not followed by food. Thus, there appear to be different ways to inter-

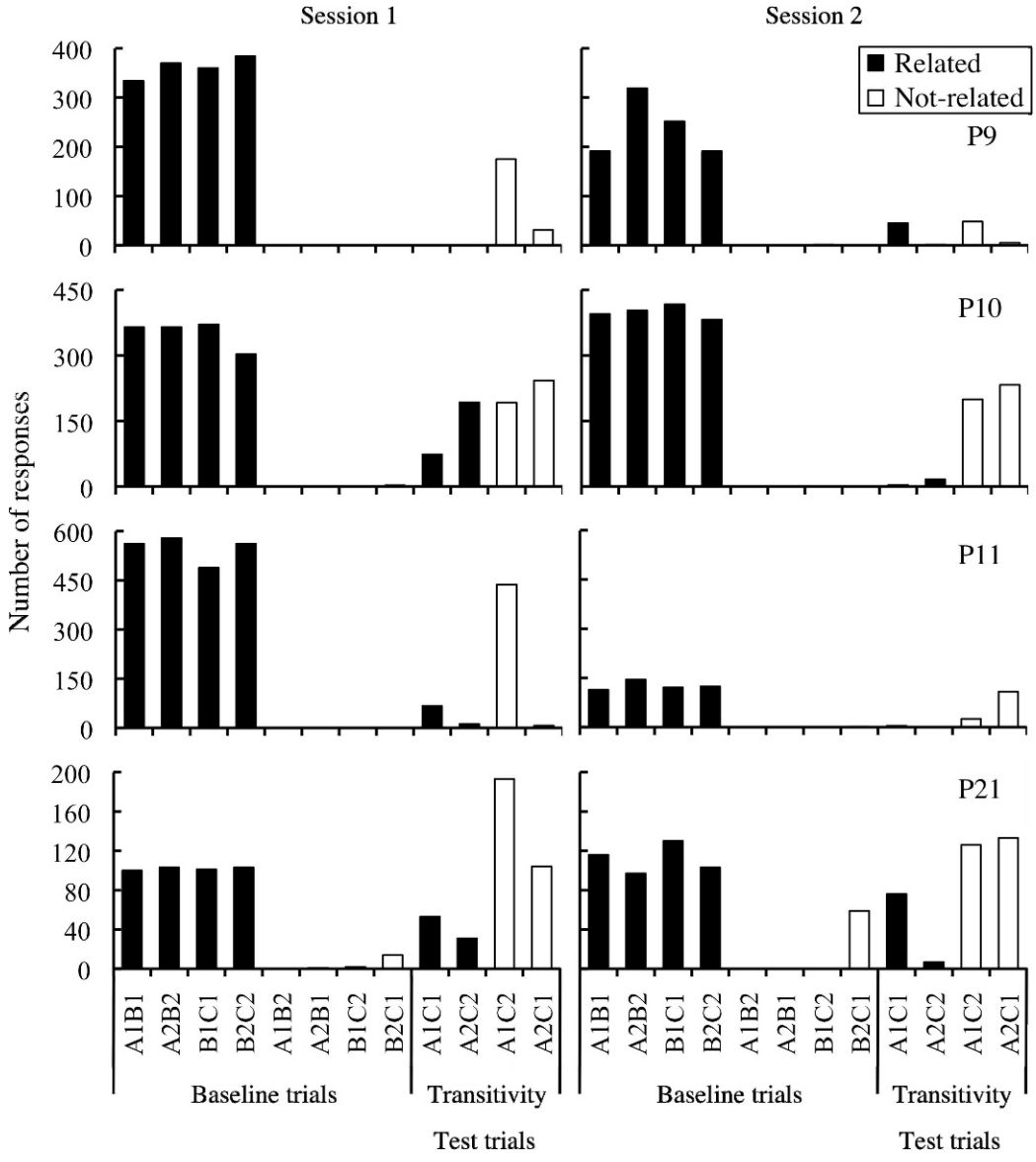

Fig. 4. Number of responses to baseline and transitivity test compound stimuli during transitivity tests for Subjects P9, P10, P11 and P21. The left portion presents the results of Session 1 and the right portion presents the results of Session 2. In each graph, the left portion presents the baseline compounds and the right portion presents the transitivity test compounds. Black columns refer to ''related'' compounds and white columns refer to ''not-related'' compounds.

pret results of *any* symmetry test procedure that does not have features to show that the component stimuli have functions that are (or can be) demonstrably separate (see Lionello-DeNolf [2009], Sidman [1986], and McIlvane [in press] for more extensive consideration of the relevant issues).

One way to assess whether symmetry tests results like those reported here are due to mere stimulus generalization would be to present the compound stimuli in both horizontal and vertical orientations during training and to test with stimuli presented in reversed positions along both dimensions. Another possibility would be to separate the stimuli spatially as in the studies with humans by Debert and colleagues (2007, 2009). If symmetry test findings were negative in either

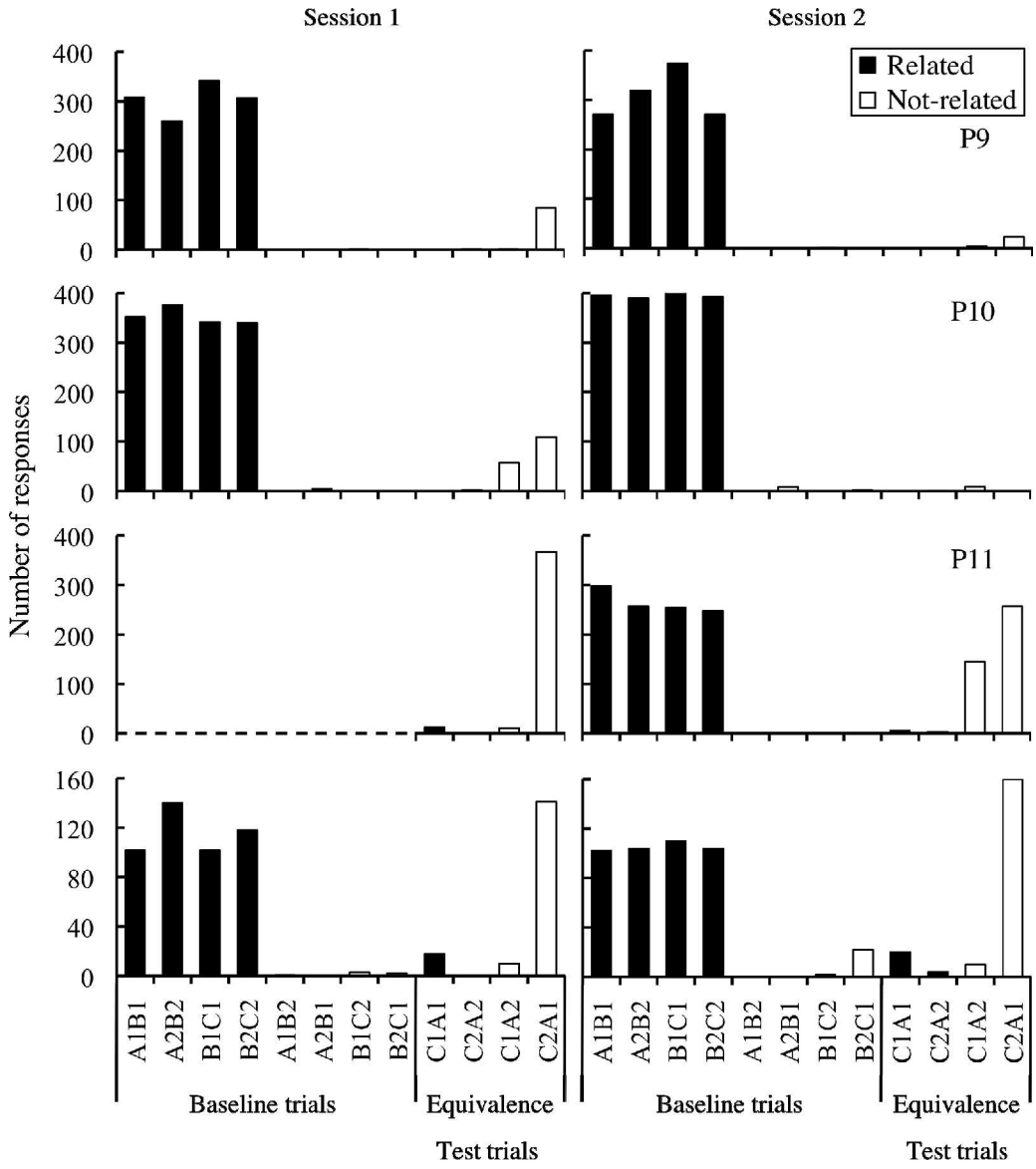

Fig. 5. Number of responses to baseline and equivalence test compound stimuli during equivalence test for Subjects P9, P10, P11 and P21. The left portion presents the results of Session 1 and the right portion presents the results of Session 2. In each graph, the left portion presents the baseline compounds and the right portion presents the equivalence test compounds. Black columns refer to ''related'' compounds and white columns refer to ''not-related'' compounds. Subject P11's baseline data from the first equivalence test session are not presented here because, as the text notes, transitivity and equivalence tests were conducted inadvertently in the same session. Therefore, baseline data are presented only in Figure 4.

case, then a stimulus generalization account becomes plausible.

As to interpreting the current transitivity and equivalence test results specifically, it seems plausible that primary stimulus generalization could have competed with the intended arbitrary stimulus-stimulus relations during AB and BC baseline training. During training, for example, pigeons learned to respond when blue (B1) was presented with red (A1) (i.e. A1B1). On transitivity tests, some pigeons responded when purple (C2) was presented with red (i.e. A1C2) and did not respond when orange (C1) was presented with red (i.e. A1C1). Did this outcome occur merely because purple is closer to blue than is orange

on the color gradient? As another example, pigeons were taught not to respond to yellow (B2) when it was presented with red (A1) (i.e. A1B2). If they failed to respond when orange (C1) was presented with red (i.e. A1C1), did the failure occur because orange (C1) resembled yellow (B2)? If so, replacing color stimuli used in this experiment with other readily discriminable stimuli might yield positive results. For example, the stimuli used by Frank and Wasserman (2005) avoided between-color generalization problems. Had we used such stimuli, perhaps our transitivity and equivalence test outcomes would have been more positive.

Another interpretation of the negative results in the transitivity and equivalence tests is that training might have taught pigeons to respond to A1B1, A2B2, B1C1, and B2C2 compound and not to respond to any other compounds – a relational analogue to ''stimulus overselectivity'' or ''restricted stimulus control'' that has been reported in feature-based matching tasks (e.g., Dube, Dickson, Balsamo, O'Donnell, Tomanari, Farren, Wheeler, & McIlvane, 2010). In this interpretation, one suggests that a go/no-go baseline training may have established relations of the ''if'' variety – to respond *if and only if* the baseline compound stimuli were present (cf. Fields, Doran, & Marroquin, 2009; Fields, Reeve, Varelas, Rosen, & Belanich, 1997).

To conclude, we believe that the results of our experiment may help focus conceptual and methodological analyses about how one goes about conducting truly compelling tests for the relational properties of potential stimulus equivalence relations. The go/no-go procedure does seem to have some compelling advantages. The present symmetry test data show that minimal changes in stimulus locations need not disrupt relations established during baseline training. The procedure is efficient in establishing all of the necessary successive and simultaneous discriminations required (cf. Saunders & Green, 1999) during baseline training. Thus, the question arises of what conditions must be in place to make a procedurally valid test for symmetry. This leads to other questions such as ''Can we yet conclude with confidence that pigeons can show symmetrical stimulus-stimulus relations in the sense implied by Sidman and Tailby (1982)? If not, under what test conditions would a positive symmetry-test outcome be thoroughly convincing?''

By contrast, we do have strong argument that the behavioral relations established in baseline training are equivalence relations (or become through gradual emergence in repeated testing, cf. Sidman, 1990) when participants pass the combined tests for transitivity and equivalence specified by Sidman and Tailby (1982). Passing such tests demonstrates empirically that stimulus displays are not unitary compounds but rather ''separable'' compounds (Debert et al., 2007, 2009; Perez et al., 2009; Stromer, McIlvane, & Serna, 1993). Perhaps go/go-go procedures could be used to *establish* component separability via multiple exemplar training (cf. Luciano, Becerra, & Valverde, 2007). If that outcome could be achieved, perhaps pigeons and other nonhuman species would come to routinely and reliably show positive results on symmetry, transitivity, equivalence, and other tests (e.g., for identity and oddity relations) that may confirm the behavioral prerequisites for true symbolic behavior.

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